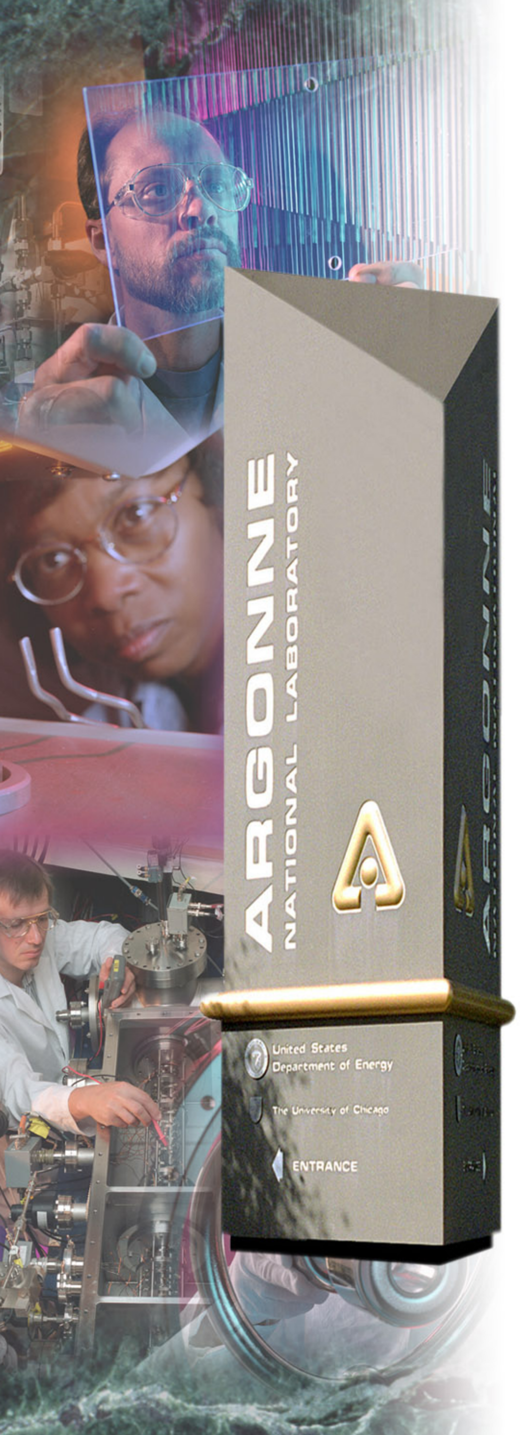

The AMIGA Modeling System: Technology Characterization and Policy Issues

Using Detailed Technology Characterizations within a Computable General Equilibrium Modeling Framework

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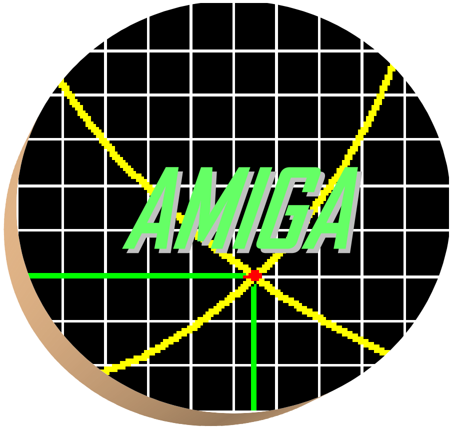
About AMIGA – the All-Modular Industry Growth Assessment Modeling System

AMIGA Modeling System, Version 4.0

- Version 1.0 was a strictly energy-economic framework developed for DOE/EERE Office of Transportation Technologies (OTT) with a 2020 time horizon and used for preparing the OTT R&D Report to Congress.
- Version 2.0 included carbon emissions with tradable permits. It tracked the NEMS Annual Energy Outlook and was used for Clean Energy Future (CEF) analysis.
- Version 3.0 incorporated the Argonne Unit Planning and Compliance model. SO_2, NO_x, and Hg emissions were added for the Jeffords-Lieberman analysis and EMF-19 scenarios.
- Version 3.1 increased representation of the transportation sector with a 2050 time horizon and was used for Pew Climate Center, Keystone scenario analysis, and EPA-Argonne Energy Future Scenarios.
- Version 4.0 adds the other (Non-CO2) greenhouse gases and the other regions of the world with a time horizon out to 2100. This model is being used for the EMF-21 scenarios.

AMIGA Is a Comprehensive Model Integrating Energy Markets, Technologies, and Policies

- **The AMIGA Modeling System is a general equilibrium model developed and supported by the Argonne National Laboratory that:**
  - Examines the impact of changes in more than 200 individual sectors (in terms of both dollar measures and physical units).
  - Integrates a detailed energy market specification within a structural economic model.
  - Allows firms to maximize net wealth and consumers to maximize intertemporal utility. In the absence of perfect foresight, agents act on approximate intertemporal rules.
  - Calculates both prices and macroeconomic variables as consumption, investment, GDP government spending, and employment.
  - Provides equilibrium paths from the present through the year 2050, with the capability of extending the time horizon out to 2100.



Computable: Modern Structured Programming

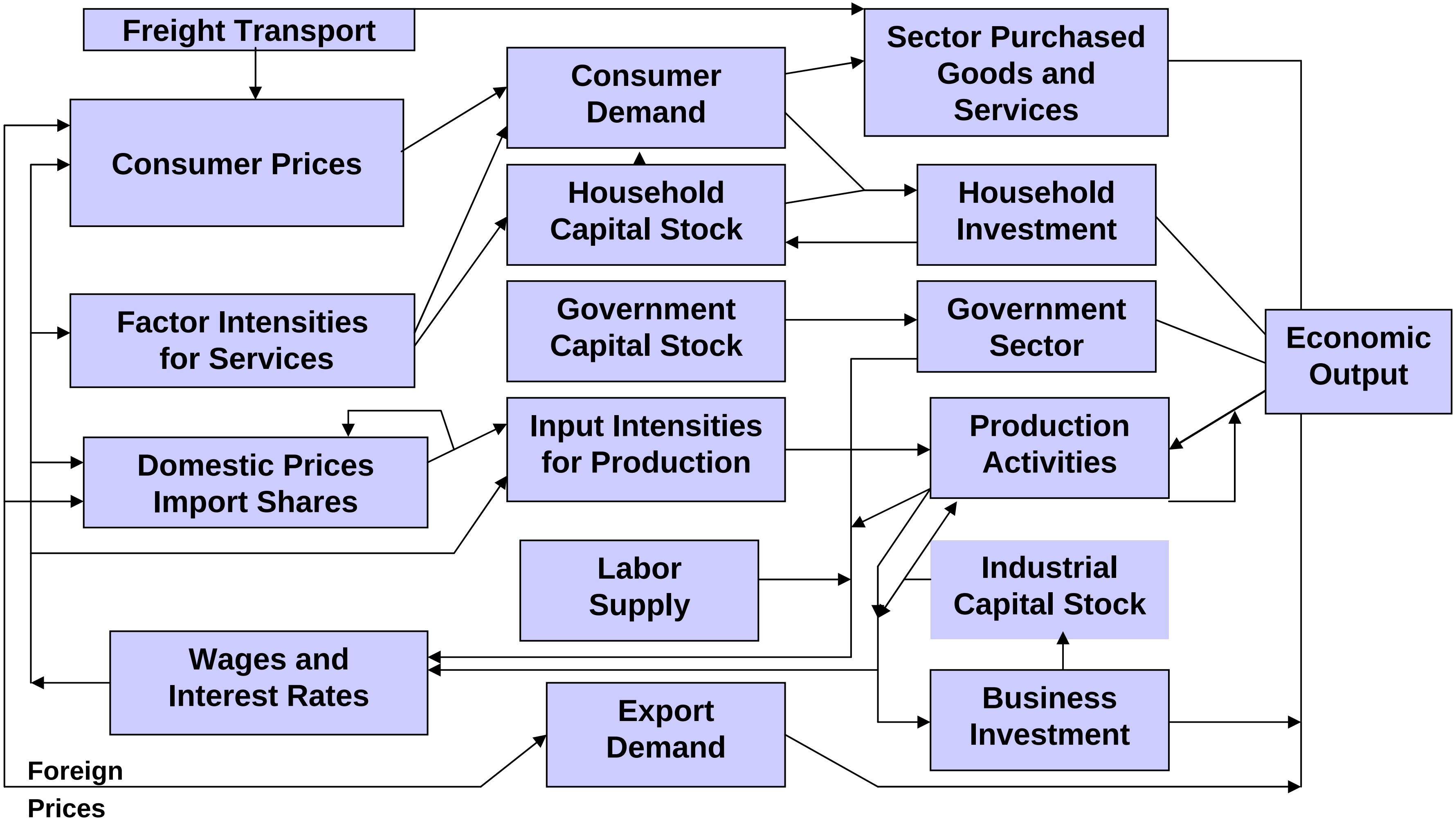
- **Programmed in the structured C language**
- **Fast convergence to solution**
  - Quick sort dispatches units and makes other least-cost choices such as pollution abatement measures
  - Hierarchy of Constant Elasticity of Substitution (CES) functions automatically provide quick decisions
- **See the AMIGA system website for**
  - Benchmark data table for 200 rows by 50 columns,
  - The Gauss-Seidel method for solving systems of simultaneous equations (i.e., where industries and modules interact).
  - Other documentation and recent studies or publications

http://amiga.dis.anl.gov

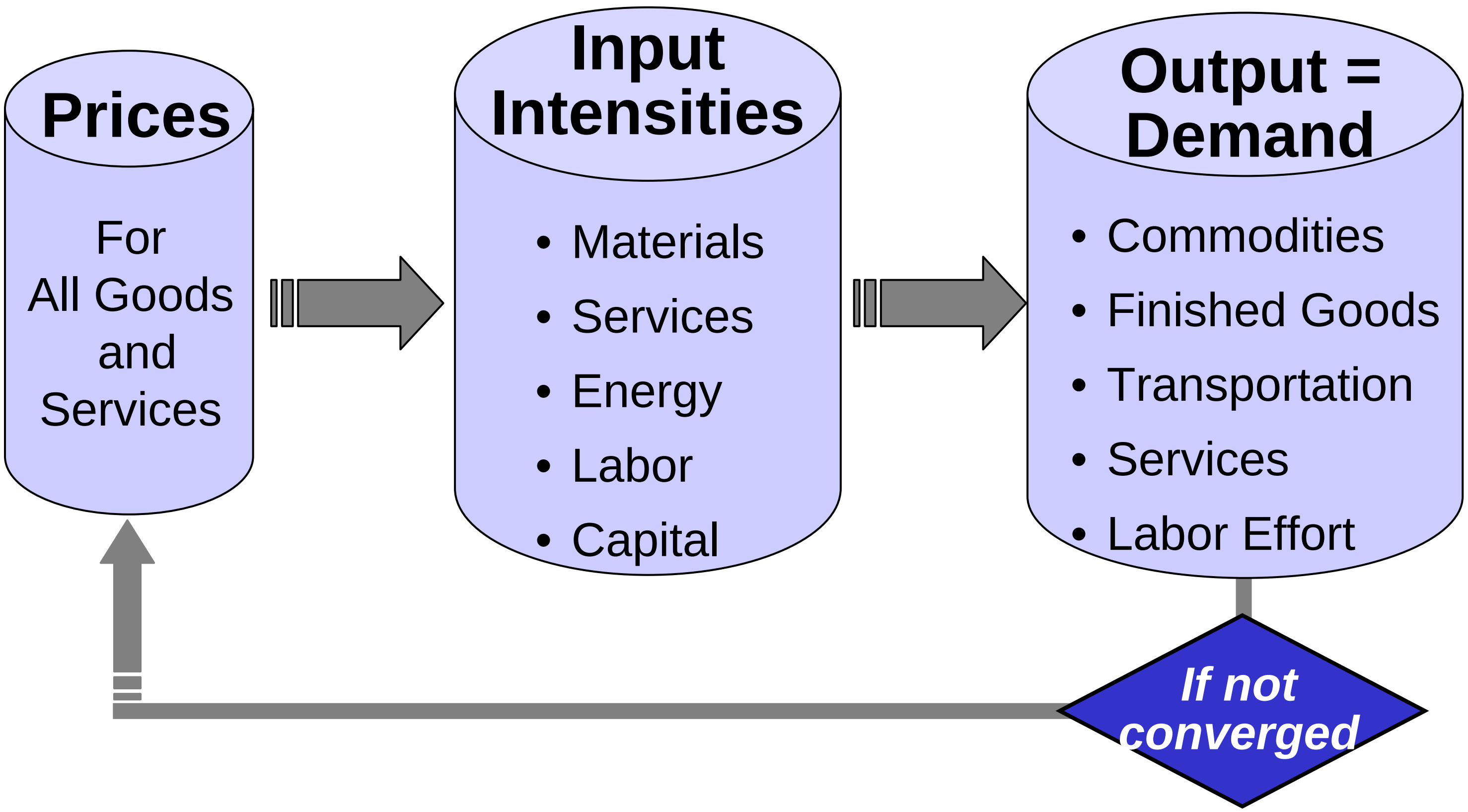
First and Foremost an Economic Model

- The AMIGA system represents growth in demand for goods and services, which in turn drives energy demand as a function of energy-intensity of new equipment purchases.
- Includes the components of expenditures,
- Shows the allocation or real resources in the economy,
- Provides an economic measure of material well-being (the equivalent variation), and
- Can incorporate the impact of externalities and spillovers as defined by policy scenarios.

AMIGA Includes the Components of Demand and the Inputs to Production



AMIGA Calculates Both Prices and Intermediate Demand Quantities



Computable within a Modular Structure

- **Vehicle Stock and Transportation**
- **Electricity Supply Capacity and Generation**
- **Process Transformations**
- **Product Manufacturing Activities**
- **Service Sectors and Government**
- **Industrial Capital Stock**
- **Buildings Capital Stock**
- **Non-carbon Greenhouse Gases**
- **Household Consumption**
- **Natural Gas Supply**
- **World Oil Pricing**

Essential Dynamic Analysis

- Growth in supply and demand for capital services
- Retirements of existing capital
- Investments for growth and replacements, with a distribution of decision criteria
- Putty-clay characteristics of the existing capital stock
- R&D and technology advance
- Adoption and learning with newer technologies
- Cumulative emissions and banking reduction credits

Expandability: We Can

- Add disaggregated goods and services (insert a row index)
- Add disaggregated or new production process or activity (insert column index)
- Add many new vehicle, generation, and end-use technologies
- Incorporate labor-leisure tradeoffs in the labor supply function
- Include endogenous technological change
- Also add the macroeconomic impact of changes in health and/or environmental expenditure patterns

Some of the Policy Drivers

- Public and private sector cooperation and partnerships
- A variety of voluntary and information programs
- Experience curves or learning from adoption
- The Technology Investment (TI) Scenario, including production incentives on both energy supply and end-use
- Research and Development
- Renewable portfolio standards
- Appliance, Equipment and CAFE standards (including tradable permits for standards)
- System of tradable permits (including banking and borrowing with the possibility of interpollutant trading)

Keeping Co-Benefits in the Picture

- **Increased Energy Security**
- **Lower world oil prices, benefiting most countries**
- **Reduced energy expenditures**
- **Reduced criteria and toxic air pollutant emissions; and potentially, the health and environmental benefits associated with emission reductions**
- **Increased productivity associated with many energy efficiency technologies**

Recalling a Basic Economic Relationship

GDP = Investment + Personal Consumption +
Government Spending + Net Exports

Hence, an “investment-led” energy efficiency strategy could lead to:

(1) greater investment in efficient/low-carbon technologies;
(2) increased spending as a result of energy bill savings;
(3) R&D, incentives, and market development programs; and
(4) reduced imports of other goods and services

Therefore, an investment-led energy efficiency strategy can lead to a small but net positive gain for the economy

Technology Characterization within AMIGA

The Major Categories of Economic Costs and Benefits of Energy Technology Investments

- **At Least Four Categories of Costs**
  - Direct Investment Costs
  - Operating and Maintenance Costs
  - R&D and Program Costs
  - Transaction and Search Costs
- **But Also at Least Four Categories of Benefits**
  - Direct Savings from Lower Compliance Costs
  - Process Efficiency and other Productivity Gains
  - Environmental Benefits not Captured within normal Market Transactions
  - Spillovers and/or learning created/induced by either the technology investment, or the R&D efforts

The Model Adds Capacity in New Energy Supply Technologies

- **Coal – 4 types of re-powering and gasification technologies,**
- **2000 existing power plants**
- **SO_2, NO_x, and mercury controls**
- **Nuclear – evolutionary and advanced designs,**
- **Gas – both conventional and advanced natural gas combined Cycle (NGCC) units, peakers, and advanced turbines,**
- **Municipal solid waste,**
- **Large combined heat and power (CHP) units by fuel type, such as natural gas or biomass,**
- **Fuel cells systems,**
- **Other distributed generation,**
- **Renewable technologies, including**

  Wind, Geothermal, Hydroelectric, Biomass co-firing, Biomass gasification combined cycle, Building Integrated PV, Solar, and other

AMIGA Also Adds Investments in Energy End-Use Technologies

- **Based on**
  - Engineering cost-of-energy estimates,
  - Supply function analysis, and
  - Consumer preferences based on a distribution of hurdle rates unique to end-use sector, energy service, and fuel type.
- **Including**
  - Light and heavy duty vehicles for both passenger and freight services,
  - Industrial processes, and
  - Building technologies.
- **Now also including**
  - Technology characterization for both carbon and non-carbon greenhouse gas emissions across all major regions of the world.

For Example: Transportation Size Classes

- **Sub compact**
- **Compact car**
- **Medium car**
- **Large car**
- **Mini vans**
- **SUV – regular**
- **SUV – large**
- **Pickup trucks and large vans**
- **Commercial trucks**
- **Medium weight trucks**
- **Buses**

Transportation Technology Choices: Engines

- Conventional gasoline
- Advanced gasoline
- Natural gas vehicle
- Methanol vehicle
- Conventional diesel by fuel sulfur content
- Advanced diesel by fuel sulfur content
- Gasoline hybrid with and w/o grid connection
- Diesel hybrid with and w/o grid connection
- Natural gas hybrid with and w/o grid connection
- Advanced gasoline hybrid with and w/o grid connection
- Advanced diesel hybrid with and w/o grid connection
- Fuel cell vehicles with and w/o on-board reformers
- Choice based on market share formula as a function of vehicle costs and attributes

Transportation Technological Change

- **Vehicle technology has been undergoing relatively continuous technical change. We represent this evolutionary technical change as improvements in the characteristics of Conventional and Advanced gasoline and diesel vehicle types.**
- **Practical, economic fuel cell technology and hydrogen storage technology would represent engineering breakthroughs. The model takes as an input assumption the dates for availability of breakthrough technologies. Their importance can be examined through sensitivity testing.**
- **Hybrid vehicles with advanced power electrics and controls represents a mid case. This is foreseeable technology that is developing very quickly.**

Energy Policy Conclusions

- Policy analysis needs to recognize that not all technology or capital is the same – new energy efficiency investments often provide significant opportunities for high social returns;
- Policy analysis should account for differences in decision-making behavior, especially where divergences from socially optimal investments exist;
- Technology policy should start early to be able to take advantage of “learning experience” to improve technology performance and cost.
- New policy directions will take time, and “low-cost” energy policy will reduce the extent of “early equipment retirements” (adjustment cost from early capital retirements is represented and measured by the area under the isoquant functions).
- Technology, Institutions and Organizations, Markets, and Behavior interact in their effects.

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